Physics 200 Name KEY 64 pts

Lab Time (circle one): 9:00am 12:00pm 3:00pm

Exam 3 – Multi-Particle Systems

November 20, 2012

This is a closed book examination. You may use a both sides of a 3"x5" notecard (or one side of a 4"x6" notecard) with equations, concepts or other soothing sonnets. There is extra scratch paper available. Your explanation is worth ¾ of the points. Explain your answers!

A general reminder about problem solving:

1. Draw a picture then create a simplified free body diagram with all forces
2. Write down what you know including coordinate frame
3. Write down what you don't know and/or want to know
4. List mathematical relationships
5. Simplify and solve
6. Check your answer – Is it reasonable? Are units correct?

- Show all work!

1. [4 PTS] The first excited state of a particular atom in a gas is 7.3 eV above the ground state. A moving electron collides with one of these atoms, and excites the atom to its first excited state. Immediately after the collision the kinetic energy of the electron is 3.1 eV. What was the kinetic energy of the electron just before the collision?
   a) 4.2 eV
   b) 5.2 eV
   c) 6.6 eV
   d) 7.9 eV
   e) 10.4 eV

The total energy is conserved so $E_i = E_f$. $KE_i = KE_f + PE_{atom}$ $PE_{atom} = 7.3$ eV and $KE_f = 3.1$ eV

2. [4 PTS] What is the rotational kinetic energy of an object rotating at 50 rad/s with a moment of inertia of 30 kg m^2?
   a) 41.7 J
   b) 1.50×10^3 J
   c) 2.25×10^4 J
   d) 3.75×10^4 J
   e) 7.50×10^4 J

The rotational kinetic energy is $KE_{rot} = \frac{1}{2} I\omega^2$

3. [6 PTS] An elastic collision is different from an inelastic collision. Indicate which of the following statements about an elastic collision are **T**rue and which are **F**alse. Explain
   a) T The sum of the final kinetic energies equals the sum of the initial kinetic energies.
   b) F The colliding objects are stretchy or squishy.
   c) F The colliding objects stick together.
   d) F The momentum is only conserved in an elastic collision.
   e) T There is no change in the internal energies of the objects (thermal energy, vibrational energy, etc.).

All collisions conserve momentum but there is no change in kinetic energy for an elastic collision. Hence there can be no change in internal energy of the objects.

The next two questions concern the collision between an 8 kg mass initially traveling at <12, 0, 0> m/s and a 12 kg mass initially travelling at <4, 0, 0> m/s. The two masses stick together after the collision.

4. [4 PTS] What is the final velocity?
   a) $< 2.4, 0, 0 >$ m/s
   b) $< 3.0, 0, 0 >$ m/s
   c) $< 7.2, 0, 0 >$ m/s
   d) $< 48, 0, 0 >$ m/s
   e) $< 144, 0, 0 >$ m/s

Since momentum is conserved $p_i = p_f$
Hence $8 < 12,0,0 > +12 < 4,0,0 >= 20 < x, 0,0 >$

5. [4 PTS] What is the increase in internal energy of the two masses?
   a) 154 J
   b) 518 J
   c) 614 J
   d) 672 J
   e) 1190 J

Energy is conserved - but kinetic energy is not conserved in an inelastic collision.
$\frac{1}{2}(8kg)\left(12\frac{m}{s}\right)^2 + \frac{1}{2}(12kg)\left(4\frac{m}{s}\right)^2 - \frac{1}{2}(20kg)\left(7.2\frac{m}{s}\right)^2 = E_{internal}$

6. [4 PTS] A solid sphere and a solid disk are both spinning at the same angular velocity. If they both have the same radius which object has more rotational kinetic energy?
   a) The solid sphere has more rotational kinetic energy
   b) The solid disk has more rotational kinetic energy
   c) They both have the same rotational kinetic energy
   d) Not enough information given to determine which has greater rotational kinetic energy.

The rotational kinetic energy is $KE_{rot} = \frac{1}{2}I\omega^2$. The moment of inertia depends on both the radius and mass so we need to know the mass of each object.

The next two questions concern two identical solid disks are placed at the same height on a hill to race. The red disk is placed on a track with a non-slip pad so it will roll without slipping. The green disk is placed on a "frictionless" pad so it will slide down the hill without rolling.

7. [4 PTS]. Which disk is traveling faster?
   a) The red disk is traveling faster.
   b) The green disk is traveling faster.
   c) Both disks are traveling the same speed.
   d) Not enough information.

Energy is conserved. The disk that is rolling uses energy to rotate the disk so the end linear velocity of that disk is less.

8. [4 PTS] Which disk has more total energy at the bottom of the hill?
   a) The red disk has more energy.
   b) The green disk has more energy.
   c) Both disks have the same energy.
   d) Not enough information.

Energy is conserved $PE_G = KE_{linear} + KE_{rotational}$
Both disks are identical and start at the same height so they have the same energy to start

9. [6 PTS] An "atom" has energy levels of -15.2 eV, -5.3 eV and -3.6 eV. A collection of these atoms is bombarded by an electron beam so that there are atoms with electrons in every excited state. Indicate which of the following energy photons will be observed (**T**rue) and which will not be seen (**F**alse). Explain.

a) __T__ 1.7 eV
b) __F__ 8.9 eV
c) __T__ 9.9 eV
d) __T__ 11.6 eV
e) __F__ 18.8 eV
f) __F__ 20.5 eV
g) __F__ No photons observed since energies are negative.

Energy is conserved and so the possible energies are those from higher (less negative) energy levels to lower (more negative) energy levels. There are only three photon energies observed from excited states to lower energy levels. Note: There would be three more photons observed for ionized atoms.

Please do the next two problems using problem solving sheets (or on additional paper).

10. [12 PTS] A square made with four 2.0 meter long nanotubes has small dense 3 kg objects placed at each corner. The nanotubes are really strong and basically massless. You want to store the maximum energy when spinning this object at a fixed angular frequency. Calculate the difference in energy for spinning it about a diagonal or about an edge.

I = 24 kg m^2 for an edge. I = 12 kg m^2 for a diagonal. Hence spinning this square about an edge will store twice the energy.

11. [12 PTS] An object with a mass of 0.15 kg hits the floor with a speed of 5 m/s after falling 59 meters. The object rebounds upward from the floor with a speed of 4.2 m/s after being in contact with the floor for 0.0016 sec. Compare the average force exerted by the floor to the gravitational force on the object.

Use $\Delta p = F\Delta t$ and find 864 N is the average force while 1.47 N is the gravitational force.

Possibly useful mathematical relationships:

$\sin^2(\theta)+\cos^2(\theta)=1$	$\sin(2\theta)=2\sin(\theta)\cos(\theta)$
$\cos(2\theta)=\cos^2(\theta)-\sin^2(\theta)=2\cos^2(\theta)-1=1-2\sin^2(\theta)$	
Derivative of a polynomial $\frac{d}{du}Cu^n = nCu^{n-1}$	
Anti-derivative (integral) of a polynomial $\int Cu^n du = \frac{1}{n+1}Cu^{n+1} + const.$	
The Chain Rule $\frac{d}{dz}f(u)=\frac{d}{dz}u\frac{d}{du}f(u)$	

Useful Data:

Mass of Earth = 6x10^{24} kg Radius of the Earth = 6.4x10^6 m	G = 6.67x10^{-11} Nm^2/kg^2 Acceleration due to gravity at the surface of the earth is 9.81 m/s^2